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Marlene H. Dortch, Secretary
Federal Communications Commission
445 Twelfth Street, SW
Washington, DC 20554

Re: Notice of ex parte communications,

- GN Docket No. 12-268, Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions
- ET Docket 13-49, Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band

Dear Ms. Dortch:
On January 15, 2016, I met with Julius Knapp, Chief of the FCC Office of Engineering and Technology. We discussed the following three issues.

Topic 1: Ways to Improve Spectrum Utilization in the TV Band. (FPTV and LPTV)
My research has shown that a change in the technology used by TV broadcasters could improve spectrum efficiency, and free a great deal of spectrum. In a region where TV broadcasters are densely packed, a modest increase in transmit power could allow broadcasters to serve the same coverage areas with 10% to 30% less spectrum. A transition from the traditional single-transmitter architecture to a single-frequency network (SFN) could free on the order of 60% of the TV spectrum – far more than is expected from the incentive auction. However, such changes come at a cost, and the value of spectrum freed would only exceed that cost where population density is sufficiently high. For the simple approach of increasing transmit power, we find that a transition is likely to be cost-effective in much of the U.S. For SFNs, higher population densities are needed.

As part of this research, we also find that low-power television (LPTV) stations and other stations with relatively small coverage areas use spectrum more efficiently than their higher-power competitors, which may have implications for the incentive auction.

Slides on this topic are attached. The issue is discussed further in research papers.[1]

[1] e.g. see R. Bettencourt and J. M. Peha, "On the Trade-off between Spectrum Efficiency and Transmission Cost in Traditional and SFN-Based Broadcast Television," *IEEE Conference on Dynamic Spectrum Access*

Topic 2: Analysis for Repacking after the Incentive Auction

We discussed the analytic techniques used to determine the borders of TV coverage areas under hypothetical conditions, and then to repack TV spectrum efficiently while preserving existing coverage areas. We discussed whether there may be better ways to perform this kind of analysis than what the FCC is planning to use.

Topic 3: DSRC-Based Vehicular Networks and Spectrum

Carnegie Mellon University has an active research program on Connected Vehicles.[2] We discussed the opportunities and challenges associated with Connected Vehicles, including issues related to spectrum management and technical standards.

Sincerely
Jon M. Peha

Networks (DySPAN), 2015. https://users.ece.cmu.edu/~peha/Spectrum_and_TV_architectures_DySPAN_2015.pdf

[2] e.g. see A. Ligo, J. M. Peha, P. Ferreira, J. Barros, "Comparison between Benefits and Costs of Offload of Mobile Internet Traffic Via Vehicular Networks," *43rd Telecommunications Policy Research Conference (TPRC)*, 2015. https://users.ece.cmu.edu/~peha/Vehicular_Network_Offloads_TPRC_2015.pdf

A Cost-Effective Way to Free TV Spectrum

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Presented at Federal Communications Commission, Jan. 2016

From work with CMU Ph.D. student Rolando Bettencourt:

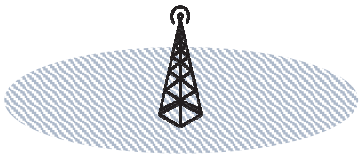
R. Bettancourt and J. M. Peha, "On the Trade-off between Spectrum Efficiency and Transmission Cost in Traditional and SFN-Based Broadcast Television," IEEE DySPAN 2015.
www.ece.cmu.edu/~peha/Spectrum_and_TV_architectures_DySPAN_2015.pdf

Television Transmission Architectures

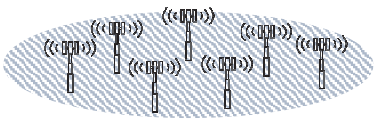
We can increase Spectrum Efficiency

- Two alternative strategies:
  1. Increase the transmit power of each broadcaster's single transmitter
  2. Replace with a multi-transmitter OFDM Single Frequency Network (SFN)

Single-transmitter



Single Frequency Network



When is value of spectrum freed greater than cost of new strategy?

Cost-Effectiveness Analysis

- Calculate incremental cost to TV broadcasters
  - For traditional TV: this is cost of increasing transmit power
  - For SFN: this is cost of building entirely new SFN
- Calculate % of spectrum freed with new technical approach
- Calculate value of spectrum freed
  - Assume value of spectrum per MHz-POP is constant: $2
- Determine when value of spectrum freed > cost
  - Some mechanism would be needed to compensate those who are incurring costs (broadcasters)

Initial Scenario

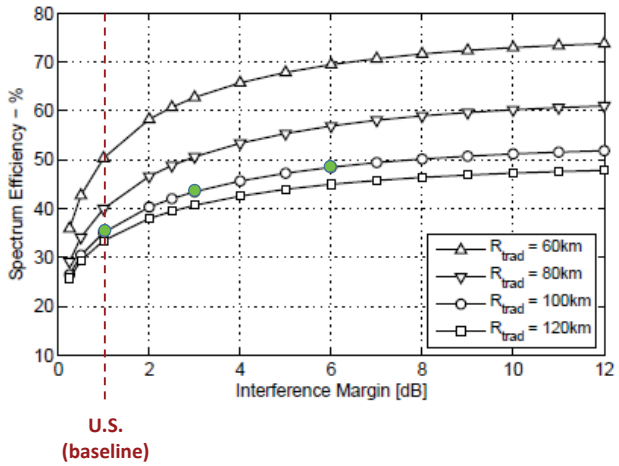
- Consider region where
  - population density is roughly constant
  - number of broadcasters serving each household is roughly constant
- All TV stations in the region are the same
  - Same architecture (traditional or SFN)
  - Same transmit power
  - Same coverage area
- Coverage area per station is fixed, regardless of technology
- Stations are packed as closely together as possible such that SINR requirements are met throughout coverage areas

Numerical Results

Traditional Broadcasting

Y-axis: Spectrum Efficiency
X-axis: Interference Margin over noise-limited design

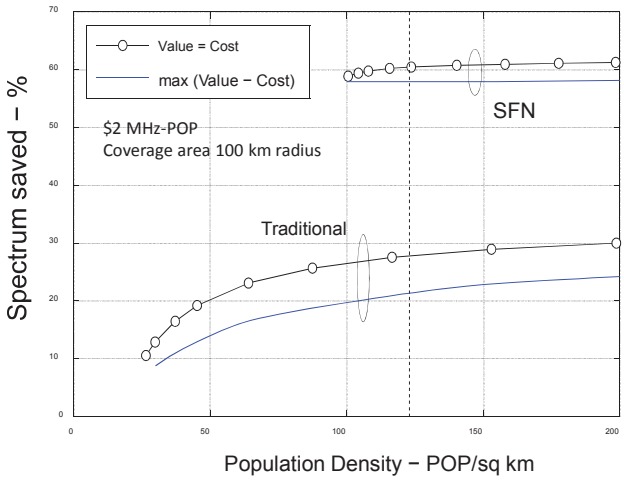
- Higher transmit power always increases efficiency
- The larger the coverage area, the lower the spectrum efficiency



Spectrum Saved with Cost-effective Strategy

New approach is cost-effective in much of nation

- If POP/sq-km > 120
  - Switch to SFN
  - Cost-effective to free up 60% of TV spectrum
  - Some areas of U.S. have POP/sq km over 120,
  - e.g. Boston to Baltimore
- If POP/sq km between 30 and 120
  - Increase transmit power
  - Cost-effective to free up 10% to 25% of TV spectrum
  - Majority of U.S. has pop density in this range



Conclusions

- Switching to SFNs can free up over 60% of TV spectrum
  - SFNs could free up to ~130 MHz of UHF spectrum at no net cost in highly populated areas. (e.g. perhaps a portion of US East Coast)
- Boosting transmit power in traditional broadcasting can free up as much as roughly 30% of the spectrum
  - Could free up roughly 10% to 25% of spectrum at no net cost in areas that represent much of US
- These savings can only be realized if there is a mechanism to appropriately compensate broadcasters who incur costs
- Broadcasters with smaller coverage areas are ***more*** spectrally efficient

Future Work

- This model does not ***yet*** include many complexities
  - In US, density of broadcasters varies greatly from market to market
  - Coverage areas vary from broadcaster to broadcaster
  - And more